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Agricultural Research

Putting the Bio in Biocontrol

This month's cover story profiles the oldest and largest—in terms of volume—ARS facility for importing insect enemies of bug and weed pests. To find out what else is on the way in this growing field, we talked to Richard Soper, ARS' national program leader for biocontrol, Beltsville, Maryland.

Ag. Res. What makes the ARS biocontrol program special?

Soper. People here and all over the world depend on ARS to supply imported beneficial insects. Last year, just at the Newark lab, 57,000 individual insects and mites of more than 30 species were received—collected in a dozen countries. After reproducing and mass producing many of these species, Newark shipped 180,000 insects to cooperators in 17 states and three foreign countries.

Ag. Res. That's a lot of insect traffic, but what impact is biocontrol having in the United States?

Soper. There have been several huge successes such as control of the alfalfa weevil—a cooperative effort of ARS, USDA's Animal and Plant Health Inspection Service (APHIS), and the states and universities. This is saving growers $88 million a year in insecticide costs. Many biocontrol successes aren't well known because they're regional or the pest is suppressed before it gets out of hand.

Ag. Res. How can you persuade farmers that biocontrol works?

Soper. We have to prove scientifically, through rigorous lab and field trials, that biocontrol can work without harming profitability.

Many farmers are already persuaded. In California, strawberry growers are using predatory mites to control lygus bugs. That state's farmers are especially eager for biocontrol because of high concern over food safety, groundwater contamination, and workers' health. Other growers are impressed by successful tests—like the one in several Texas cabbage fields last spring. The test involved ARS, a commercial insectary, and several growers using beneficial wasps and bacteria and very small amounts of insecticide.

Ag. Res. What is ARS doing to get more biocontrol insects produced in the private sector?

Soper. Dozens of insects are available commercially, although sales run only about $2 million to $3 million a year. The potential is vast, but most firms are too small to mount research and development to improve production methods. Most insect rearing is done by public organizations such as APHIS and the states and universities.

One big need is artificial diets to bring down the cost of rearing vigorous insects on a mass scale. Today, lab-rearing often means having to rear a predator's insect or plant prey or a parasite's insect host. That's messy, costly, and time-consuming. We are making progress, such as a joint project with industry on an artificial diet for a promising parasitic wasp.

Ag. Res. Is biocontrol the only way to go?

Soper. Probably not. For a typical crop, the goal should be to make biocontrol the first line of defense and integrate it with other strategies now available or being studied. Those strategies can include pest-resistant crop varieties, cultural practices that reduce pest pressure, and lures—like chemical mimics of an insect pest's sex attractant—to make the pests come to the insecticide instead of covering the field with it.

Ag. Res. How has the easing of East/West tensions affected biocontrol research?

Soper. We're beginning the third year of far more extensive joint explorations with the Soviets and Chinese. And in eastern Europe, we're negotiating a new partnership with Yugoslavia, Hungary, Czechoslovakia, Bulgaria, Romania, and Poland. They, as well as the United States, will benefit from having new biocontrol agents. Our first targets are natural enemies for pests of potatoes, fruit, and wheat.

Ag. Res. What will U.S. biocontrol look like in 10 to 15 years?

Soper. The commercial industry will be larger, as efforts by ARS and others to help develop new products and processes bear fruit. And we'll know much more about how to make biocontrol work in crop fields.

One thing is for sure—we'll be exploring for enemies of pests we don't yet have in this country. New ones invade about every 3 years.

Agricultural Research

Cover: Convergent lady beetles *(Hippodamia convergens)* are imported for study at the ARS Beneficial Insects Introduction Research Laboratory in Newark, Delaware. Photo by Scott Bauer. (K-4249-1)

Page 17

Page 19

Page 21

4 It's "Bugs-R-Us"
Before beneficial insects can enter the United States, they must first put in some time in quarantine.

13 Spying on Silage Inoculants
How effective are these bacterial innovations?

14 A New Way To Grow Tomatoes
Looking to grow bigger and better tomatoes? Here's a new mulching plan.

16 Computers Guard the Granary
And it's a good thing, too. Some nasty insects keep trying to get in.

18 Exotic Fruits Promise Taste of the Tropics
They're tucking away snippets of germplasm in Hawaii.

21 In Antibodies, Bigger Isn't Always Better
When cows get mastitis, it's an udder shame. Little white cells to the rescue!

22 Agnotes:
Skipping Preplant Irrigation Saves Water, Cash
Insecticide Adherence Triples With Soybean Oil
Sorghum Cleanses Nitrogen Laden Soil
Please Release Me—But Slowly

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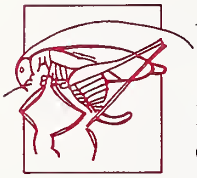
It's "Bugs-R-Us"



Across the road from the huge Chrysler assembly plant in Newark, Delaware, a different sort of factory specializes in foreign imports.

The imports—flies, wasps, beetles, and other bugs—will wage a deadly but nonchemical war against devastating agricultural pests.

The good bugs' staging site, tucked next to a pasture on the grounds of the University of Delaware, is the Beneficial Insects Introduction Research Laboratory of USDA's Agricultural Research Service.

Here, a team of three research entomologists conducts lab and field studies of natural enemies for some of the worst pests, such as gypsy moths, tarnished and alfalfa plant bugs, and Russian wheat aphids.

The lab also serves as an Ellis Island for tens of thousands of beneficial bugs. The insects are collected in foreign countries almost entirely by ARS scientists based in U.S. or overseas labs.

Good Bugs In, Good Bugs Out

The new arrivals are quarantined "to make sure the shipment has no contaminants, such as mites that would attack a beneficial insect," says Lawrence R. Ertle, the lab's quarantine officer.

He also arranges for background checks confirming each bug's scientific moniker before rearing and distributing it.

If descendants of immigrant bugs pass rigorous research trials, they're let go. Mostly, they're released by the millions in seasonal pest-control programs or freed in smaller numbers to make new, year-round homes in crop fields or forests.

Last year, 253 batches of insects arrived in Newark from a dozen

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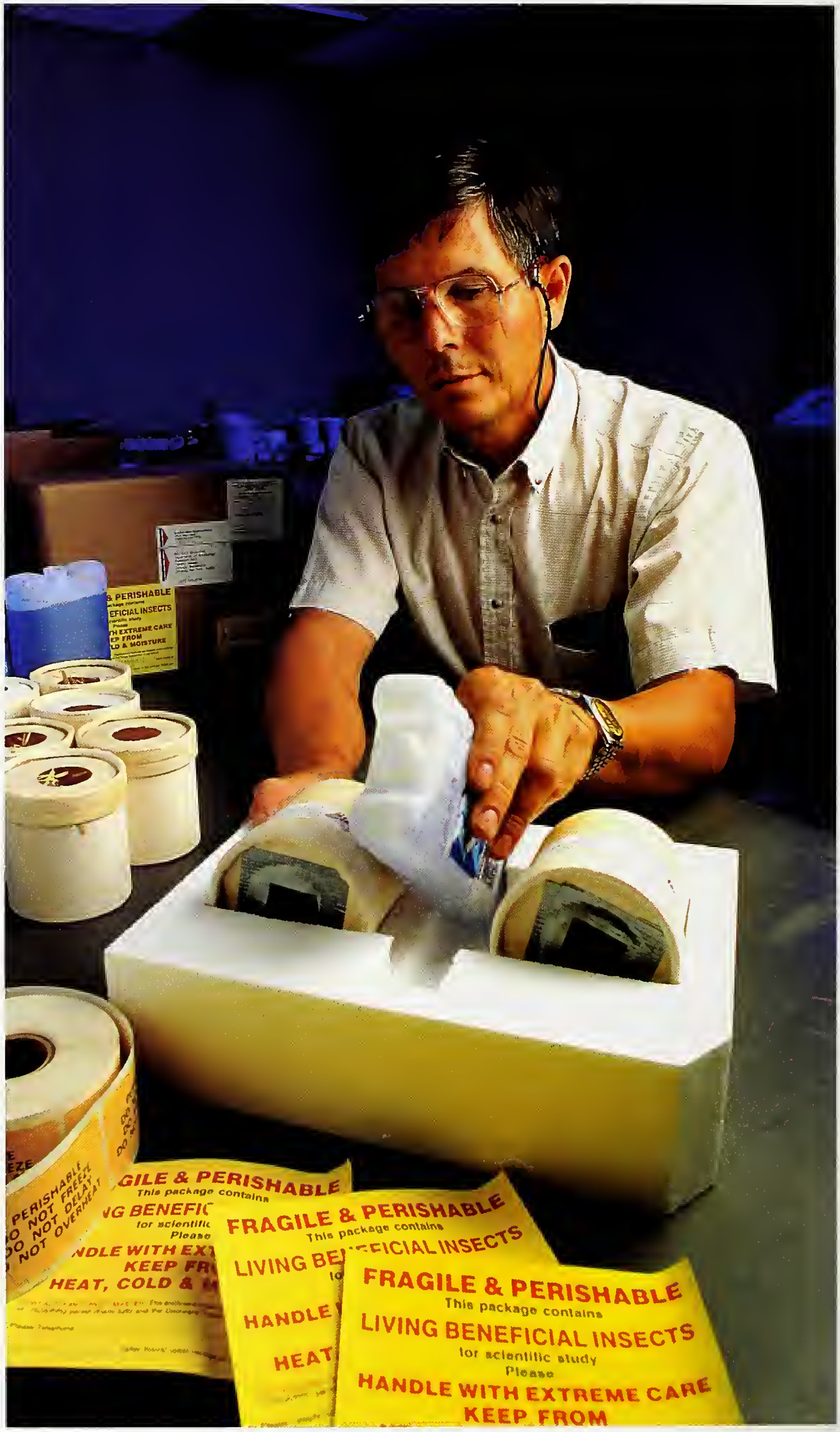


Entomologist and quarantine officer Larry Ertle gently places beneficial insects in custom-designed packaging for shipment. (K-4183-12)

There's a lab in Newark, Delaware, that is a scientific ark, brimming with beneficial insects and riding a surging tide of interest in biological pest control.

countries: Argentina, Brazil, Canada, Chile, China, France, Germany, India, Indonesia, New Zealand, South Korea, and the Soviet Union.

The bug-importing business tends to be a seasonal affair, says Ertle, with fall, winter, and spring relatively slow times for incoming shipments. June is different: that's when three-fourths of 1990's shipments arrived—nearly all from the European Parasite Laboratory in France.

During that same year, 410 lots of bugs left Newark for cooperators in ARS, other agencies, universities, and private insectaries in 17 states and 3 foreign countries.

Fully 238 of the outbound lots went to ARS and a cooperating agency, Washington State's Department of Agriculture. Nearly all were Korean and Chinese *Ageniaspis fuscicollis* wasps, parasites of the apple ermine moth, received during the summer.

After these wasps cleared quarantine, Ertle eyeballed each of the 36,950 adults (21,962 females) under a microscope to make sure they were really *A. fuscicollis*. Then, from mid-July to mid-August, he shipped them in several lots to ARS entomologist Thomas Unruh, based in Yakima, Washington, and a colleague at the state's Department of Agriculture.

"The scientists were on the move, releasing wasps at many sites, so we sent wasps to various places to keep up with their itinerary," Ertle says.

Have Bug, Will Travel

Lab technician Kenneth S. Swan is the receiver for most of Newark's newly arriving imports. "Usually this means going to the Philadelphia airport, where I sign the forms to get the bugs released to me and load them into our van," he says.

To give traveling insects a safer, cozier journey, Swan and former Newark entomologist Richard Dysart (now based in Sidney, Montana) devised a reusable bug-shipping box in 1978. They got the idea from cut-to-fit Styrofoam packing used to ship fragile equipment like computers and stereos.

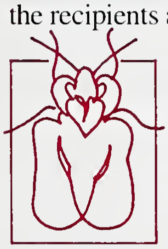
The container consists of two slabs of insulating foam with three molded cutouts. Two cutouts carry round specimen boxes with tight lids. The third holds a pint container of coolant to keep bugs from overheating in transit.

"Three-fourths of the insect labs we deal with use this kind of container now," says Larry Ertle.

Inside the Bug Vault

Three sets of heavy steel doors lead into the quarantine's main work area, a 20- by 12-foot clean-up room with a large sink and an autoclave—a gizmo resembling an industrial-size washing machine. It uses heat and pressure to sterilize material to be scrapped, like "plant parts that come in with a shipment, packing material, hyperparasites, dead hosts—anything that must be disposed of," says Ertle.

The clean-up room also has two stainless-steel refrigerators. "We keep some bugs in the cooler to slow their development," Ertle notes, "because the recipients aren't ready for them, or it's the wrong time of year to release them in the field, or we're waiting for results of identification work.



"The insects usually aren't much trouble if they get a nutritious diet, are kept at the proper temperature and humidity, and get exercise."

He's not joking. Once a day, even on weekends and holidays, Ertle or Swan removes bug-filled containers from the refrigerators and puts them by a window. There, the insects warm up, stretch, soak up some light, and walk around their paper or plastic prisons.

Even though insects are carefully packed for transit, "we have to act fast once they get to the quarantine," says Ertle. Newly arrived packages are taken straight to the unpacking room in a high-security area just past the clean-up room. Unpacked eggs and immature insects are taken to another high-security cubicle until they emerge as adults. Then they go to one of the quarantine's two rearing rooms, where a new generation will be raised.

One of the more unusual items to enter Newark's quarantine this year is the "parasite pill." Each capsule, made

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***Trichogramma* wasps are packaged in shipping capsules for later release in corn fields. Bags are color-coded according to insect maturity to help researchers determine optimum release dates. (K-4249-15)**

of soft gray cardboard and about the size of an oyster cracker, holds about 500 eggs of the Mediterranean flour moth. And inside each moth egg is a surprise for European corn borers in Iowa: an egg of the parasitic wasp *Trichogramma maidis*.

This wasp delivery system, called Trichocaps, has been successfully tested and used for about 10 years in

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Scymnus frontalis **(left) and** *Coleomagilla maculata* **(right) beetles feed on pea aphids. (K-4179-19)**

France. But the capsules' first U.S. tryouts came this past summer.

Last spring, after wasps hatched from a sample of a small test shipment and Ertle determined that the sample was "clean," he completed paperwork required by USDA's Animal and Plant Health Inspection Service. APHIS, which issues permits for all imported bugs, soon gave the go-ahead for a French firm to ship Newark thousands of Trichocaps containing 4 million wasp eggs divided into lots of 100 Trichocaps.

After testing a sample from each lot, Ertle obtained APHIS approval to ship the Trichocaps to Iowa State University for cooperative field tests with ARS and Pioneer Seed Co.

"The test is part of a comparative economic study of biological controls—the first of its kind," according to research leader Leslie Lewis at the ARS Corn Insects Research Laboratory in Ankeny, Iowa. He says the 2-year study, on 1-hectare (2.47-acre) plots of Pioneer corn seed production fields, aims to find out how well—and how economically—the European corn borer is controlled by the wasps, by the bacterium *Bacillus thuringiensis,* or by the fungus *Beauveria bassiana.*

During this past summer, Iowa State University entomologist David Orr scattered Trichocaps in the plots.

"In France," says Orr, "they've gotten an average of 74 percent control with the capsules and 72 percent with insecticide for the same cost. We want to know if Trichocaps can be a cost-effective alternative for farmers in this country."

Newark's role as an import and distribution center goes hand-in-hand with the lab's own research. A case in point is a wonder-wasp with the tongue-twisting name of *Coccygomimus disparis.*

Newark has imported these wasps since the 1970's from collections in

This wasp delivery system, called Trichocaps, has been successfully tested and used for about 10 years in France. But the capsules' first U.S. tryouts came this past summer.

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Coccygomimus disparis **wasp inserts its eggs in a gypsy moth pupa. (K-4185-18)**

India, Japan, Korea, and China. ARS and cooperators in 16 states have freed more than 800,000 of them.

The wasp has a lot of help—from other ARS scientists and technicians in the United States and at the ARS Asian Parasite Laboratory in Seoul, South Korea, as well as the New Jersey Department of Agriculture, Pennsylvania Bureau of Forestry, Delaware State College, and other universities.

"A few years ago, first new gypsy become established in the United States in 50 years," says Newark entomologist Paul W. Schaefer.

While most parasitic wasps are gnat-size or less, *C. disparis* is about 10 times bigger: a sleek, coffee-colored inch of aerodynamics.

The female wasp lays its eggs inside the pupal cases of soon-to-be-adult gypsy moths, attacking about 200 pests over a 3-week period. One parasite develops per pupal case, devours the pest from the inside, and emerges as an adult.

"This wasp doesn't sting people or animals, even though it's bigger than some wasps that do," notes Schaefer.

Size helps but isn't the key reason the wasp got established so readily. "This wasp's best advantage," says research leader Roger Fuester, "is that it thrives on other pest species when there aren't many gypsy moths around." That's critical: Newark studies have shown that gypsy moth parasites often fail to take hold unless the moths are fairly abundant.

University of Minnesota entomologist Willis Schaupp and colleagues have released some 3,600 *C. disparis* wasps since 1989.

While the state has exterminated small invasions of gypsy moths, Schaupp wants the wasps to form part of a vanguard of natural enemies ready to attack the moths if and when they invade in large numbers.

In the meantime, he hopes that "even if the state escapes large invasions of gypsy moths, the wasps will

Biocontrol Quarantines

Besides Newark, ARS has six quarantine facilities for imported biocontrols of weed or insect pests in the United States: at Albany, California; Frederick, Maryland; Stoneville, Mississippi; Ithaca, New York; and College Station and Temple, Texas.

ARS researchers also work in quarantines operated by Montana State University in Bozeman and by the Florida Division of Plant Industry in Gainesville. ARS has cooperative arrangements with more than a dozen other quarantines at universities and federal and state agencies.

Overseas, ARS scientists explore for, identify, study, and export biocontrol agents from their bases at ARS laboratories in Argentina, Australia, France, and South Korea. ARS also conducts joint biocontrol explorations and studies with scientists from the Soviet Union, China, and other countries.

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Research entomologists Roger Fuester (left) and Paul Schaefer collect *Calosoma* beetles and mark them to identify their sex. (K-4178-18)

do us a favor by ganging up on forest tent caterpillars, eastern tent caterpillars, and fall webworms."

But Schaupp wanted to release wasps that hadn't been reared for several generations in a lab "where they can become conditioned to looking for food in the bottom of a cage instead of on tree branches in a forest." So he asked Schaefer for wasps that were "as near to wild as possible."

Schaupp's first shipment—from Korea via Newark—arrived in 1989.

The second shipment, in 1990, was from China. Early that summer, pupae of apple ermine moths harboring wasp larvae were rounded up in Shanxi Province, China. The pupae were collected by ARS' Robert Pemberton of the Asian Parasite Laboratory in South Korea and Wang Ren, director of the Sino-American Biological Control Laboratory in Beijing.

Three lots of immature wasps arrived in Newark in mid-July 1990. When adults began to emerge, quarantine officer Larry Ertle sent a few specimens to scientists at ARS' Systematic Entomology Laboratory at the Smithsonian Institution in Washington, D.C. [See *Agricultural Research,* February 1990, pp. 8-11] When they positively identified the wasps as *Coccygomimus disparis,* Ertle sent 28 to Schaupp.

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Calosoma beetle attacks and feeds on a gypsy moth caterpillar. (K-4187-8)

Schaupp used these wasps to rear a new, larger batch that was only one generation removed from the wild Chinese parents.

"To precondition these adults for the hosts they'd be finding," says Schaupp, "we brought them webworm and tent caterpillar pupae from the field to practice on."

Last fall, he and colleagues released about 2,000 wasps at sites near the Minneapolis-St. Paul metropolitan area. "That's where the gypsy moth would first be likely to show up in large numbers," he says.

Last spring, for the first time, Schaupp recovered young wasps near one of the sites, proof that some of the Chinese wasps had found mates and laid eggs.

"We're ahead of schedule and very happy for it," says Schaupp, who hadn't expected to find the wasps so soon.

While *Coccygomimus disparis* is a relatively recent arrival, an old beetle import is spreading new trouble among gypsy moths. Released in New England since 1906, the bright green caterpillar hunter *Calosoma*

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The tarnished plant bug is reared in the lab as a factory for parasites. (K-4186-11)

sycophanta wasn't seen in Delaware until 1984.

"It seems to be slowly following the gypsy moth's own spread," says Paul Schaefer. "I'd like to see this beetle tried farther west, such as Michigan, where the moth recently invaded."

Calosoma acts as if it has a mighty grudge against gypsy moths. "Sometimes it will attack and chew up a gypsy moth caterpillar just a little, leave it for dead, and go find another one," says Schaefer. One beetle can eat as many as 100 to 150 gypsy moth larvae in a season.

"The strangest thing about this beetle," notes Roger Fuester, "is that if the adult doesn't find a lot of gypsy moths, it won't reproduce. It may eat a few caterpillars of some other moth species, but then go back underground and try again next year."

The *Calosoma* beetle is part of an elite group. Of the more than 50 imported gypsy moth biocontrols, it's one of only 15 to 20 to become settled in the United States—primarily the Northeast and mid-Atlantic regions.

"We don't have as complete a team of natural enemies in this country as in Europe or Asia," Fuester says. "And we don't have any illusions about eliminating the gypsy moth completely. But we think it's feasible to cut back the number of years in which severe damage occurs—from 4 in 10 to perhaps 1 or 2."

Sometimes *Calosoma* will attack and chew up a gypsy moth caterpillar just a little, leave it for dead, and go find another one.

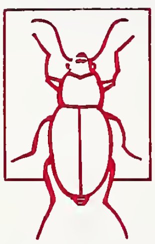
Far better known than *Calosoma* beetles are lady beetles, the most famous biological controls among farmers and home gardeners in the United States. The most common domestic species, *Hippodamia convergens,* will eat dozens of pesky aphids per day—if it's hungry.

Newark imports, rears, and distributes more specialized models of lady beetles that are found overseas by ARS scientists. Enthusiasm for them has surged because of the Russian wheat aphid, first spotted in the United States in 1986 and already considered one of our grain farmers' worst pests in the West.

Imported lady beetles released so far haven't begun to work against this aphid, says Schaefer.

"We think that's because it's just too soon," he says. "Natural enemies can take years to become established and start taking a toll. But also, wheat leaves under attack by the Russian wheat aphid roll up lengthwise around it, almost like a tiny green scroll." That helps shield the aphid from chemical sprays and, some scientists speculate, from many natural enemies.

Most lady beetles, the theory goes, are too big to squeeze inside the rolled leaf and get at the aphid. "But that isn't at all clear," Schaefer says. "Scientists overseas, as well as people monitoring lady beetle levels in this country, have found lots of them in aphid-infested fields. The beetles must be finding food or they wouldn't be there."



Still, scientists are covering their bets by trying more economy-size lady beetles, like *Scymnus frontalis,* discovered in 1988 in Turkey by scientists from the European Parasite lab. At 4 millimeters, it's about half the length of the American *H. convergens.* Colonies of *S. frontalis* at Newark feed on tiny pea aphids raised by the hundreds on potted fava bean plants.

In a rearing room, Schaefer takes a fava bean plant, turns it sideways and taps it, knocking dozens of aphids onto a tabletop. He then sweeps them up like crumbs and rations them out to lady beetles in pint containers. About a dozen containers hold lady beetles in different developmental stages, from pinhead-size larvae to mating adults.

Quarantine chief Larry Ertle and lab technician Kenneth Swan ship adult lady beetles to researchers and other cooperators, mostly to the Biological Control Laboratory of USDA's Animal and Plant Health Inspection Service in Niles, Michigan.

In 1990 and 1991, according to Niles entomologist Robert V. Flanders, APHIS reared and released hundreds of thousands of *S. frontalis* and other lady beetles in dozens of aphid-infested grain fields in the western United States. The releases were part of APHIS' National Biological Control Program against the Russian wheat aphid and other pests, says Flanders, who coordinates the program.

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Entomologist Larry Ertle conducts preliminary examination for contaminants in *Trichogramma* capsules. (K-4181-10)

"I don't know if *Scymnus* will have a better shot at getting at aphids inside the leaves," he says, "but one thing that makes it stand out is its unique egg-laying behavior. While other lady beetles lay their eggs in masses of 10 to 50 on a single leaf, *Scymnus* lays one egg at a time, then goes somewhere else and lays another. That may mean it can survive at lower aphid densities, which may further imply it is a good control agent."

A different lady beetle import—three to four times larger than *Scymnus*—also has a greater capacity for gorging on aphids. It's *Coccinella septempunctata,* the sevenspotted lady beetle, imported through Newark since the 1950's.

"One adult beetle of this species," says Schaefer, "can eat 100 to 250 aphids per day. In the lab, a sevenspotted larva averages 200 pea aphids over the course of its 8-day development."

Newark and cooperators helped the sevenspotted take hold in the East in the 1970's. APHIS began scattering it through the West in the 1980's. The beetle became established in all the western states after APHIS let go 350,000 in the Pacific Coast states and Nevada in 1988 and 1989.

The sevenspotted lady beetle now occurs in all 48 contiguous states, Canada, and Mexico, says Flanders, and is "really going to have a major impact in agriculture. It could also become the next popular backyard lady bug you'll be able to buy in retail garden shops.

"In some areas, it has moved in like crazy on apple aphids in orchards, pea aphids in alfalfa, and cereal aphids and greenbugs in grains. We won't know the full impact for several years, and we're still getting new strains coming through Newark."

Wasps Tangle With Alfalfa Pests

The sevenspotted lady beetle may be well on its way to conquering aphids. But other insects imported and studied at Newark are just beginning to set up shop.

Newark entomologist William Day aims to widen the domain of the quarter-inch-long *Peristenus digoneutis* wasp. Its chief quarry, the tarnished plant bug, sucks sap from flowers, young fruits, and seeds. But the bug doesn't live long enough to get the chance if a female *P. digoneutis* attacks it in the nymph stage.

"A few days after she stings one and lays an egg in it," he says, "a wasp larva hatches and eats it.

ARS researchers in France began collecting, testing, and shipping this wasp to Newark in the early 1970's.

From 1979 to 1983, Day made releases in northern New Jersey. By 1990, the wasps were parasitizing 30 to 90 percent of tarnished plant bugs in alfalfa fields Day sampled. They had also spread themselves across the state border into Orange County, New York, 35 miles from the release sites.

"That may not seem far," he says, "but it's encouraged more researchers to give it a try in other parts of the country."

Scientists at the Universities of Massachusetts and New Hampshire have begun new studies to check whether *P. digoneutis* can protect strawberries grown without insecticides. And Day has received new inquiries from scientists in six other states and Canada.

In Mississippi, ARS entomologist Gordon Snodgrass plans to see if *P. digoneutis* can rein in tarnished plant bugs that attack cotton. Next spring he will release the wasps—still in cocoons—near the Mississippi Delta in an alfalfa field with a natural infestation of plant bugs. He wants the alfalfa to be a natural reservoir for the wasps.

"When the wasps emerge, I hope they'll become established on plant bugs in the alfalfa and then spread to attack others that live on wild host plants near cotton fields," says Snodgrass, who is with the Southern Insect Management Laboratory in Stoneville.

On the wild plants, the pests breed a springtime generation that later invades cotton. Releasing wasps in cotton wouldn't work, he explains, since most fields get early-season insecticide applications that kill beneficials along with pests.

An Oak View, California, firm—Rincon-Vitova Insectaries, Inc.—has received starter colonies of *P. digoneutis* to release against the lygus bug, a notorious enemy of strawberries, cotton, and seed alfalfa.

"The wasps could be especially useful if they help out on lygus bugs," says Day. "California doesn't have a good parasite for the pest's nymph stage. Plus, several insecticides registered for use on lygus probably won't be re-registered, so nonchemical alternatives will become more important."

Comeuppance for the Alfalfa Weevil

In the 1970's, Day and colleagues helped pioneer one of the most successful biocontrol battles of the century. The enemy: the alfalfa weevil, a voracious pest from Europe that had invaded the western states at the turn of the century.

During World War II, the weevil also entered in the East; by 1980, its reach was coast to coast.

"Until the late fifties," Day notes, "chemical control was king and there was a lot of official skepticism about biocontrol in general."

But times were changing. One sign of that was the discovery, in the mid-sixties, of anti-weevil pesticides in cow's milk. "Our lab then hired additional people to attack the weevil problem, though we'd actually begun importing and releasing parasites in the late 1950's."

Through the 1960's and 1970's, Newark scientists released millions of about a dozen species of weevil parasites.

In the late 1960's, a battery of about six species—mostly *Bathyplectes* and *Microctonus* wasps—had the pest under control in New Jersey. "In the early 1970's," says Day, "Rutgers University found that the percentage of New Jersey alfalfa growers using pesticides against the weevil had dropped from 93 percent to 7 percent."

By 1980, beneficial parasites had a stranglehold on the weevil in 10 states in the mid-Atlantic region and New England. "We were seeing powerful mortality—about 80 percent in all," Day says. Less than one-fourth of the millions of acres of alfalfa in these states needed pesticides against the alfalfa weevil.

In Mississippi, ARS entomologist Gordon Snodgrass wants to see if *Peristenus digoneutis* can rein in tarnished plant bugs that attack cotton.

The successes of the releases by ARS and cooperating agencies prompted APHIS to take the parasites nationwide in 1980.

In a 1989 report of a study by University of Massachusetts economists, biological control of the alfalfa weevil was estimated to be saving growers across the country $88 million annually in pesticides and application costs.

"No single parasite would have made a dent," Day says, "because one female alfalfa weevil can lay as many

as 4,000 eggs. It was the total combination that did the trick."

That, plus the human team: insect researchers and collectors in overseas labs; quarantine personnel; APHIS biocontrol workers; ARS, university, and state scientists; federal, state, and commercial insectaries.

Without these sponsors, weevil-killing wasps and other biocontrol bugs would have remained in the old country, stinging or nibbling pests in obscurity.—By **Jim De Quattro**, ARS.

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Orient Express for Wasps

Rural China was the starting line for thousands of beneficial wasps that disembarked at Newark, Delaware, in the summer of 1990. ARS scientists recruited the tiny insects to battle the apple ermine moth—a pest that threatens Washington apples.

Entomologist Robert W. Pemberton and colleagues collected the wasps, known as *Ageniaspis fuscicollis.*

Pemberton, director of the ARS Asian Parasite Laboratory in South Korea, says Chinese villagers were puzzled and amused that strangers would venture to their province to look for insects in trees.

"In one village," he remembers, "we were checking apple trees next to a school playground. Suddenly we were surrounded by laughing, excited children. We soon learned that most of them had never seen a Caucasian before."

From Chinese apple orchards and lone trees, Pemberton gathered dry, mummified remains of ermine moth caterpillars. Hidden inside each stiff grey caterpillar corpse were immature *A. fuscicollis* wasps.

Earlier, female wasps had laid their eggs inside ermine moth eggs. The moth eggs hatched into small caterpillars. But the caterpillars were doomed because each wasp egg had become a chain of embryos that eventually formed about 50 to 135 young wasps. The wasps fed on the unlucky caterpillar, killing it.

The scientists found the moth mummies in sticky webs woven at twig junctions and between branches.

"The webs feel something like cotton candy," says Pemberton. "In China, we spent nights working in our rooms, sorting mummies from the webbing."

In June and July of 1990, Pemberton air-freighted 3,500 mummies to ARS colleagues in Newark. When adult wasps emerged from the mummies, the Delaware scientists shipped them to entomologists such as Thomas R. Unruh at the ARS Fruit and Vegetable Insect Research Unit in Yakima, Washington. Unruh has released several promising natural enemies of the apple ermine moth in Washington. These include *Ageniaspis* wasps collected by ARS scientists in Europe as well as Asia.

In large numbers, ermine moth caterpillars can munch the leaves off an apple tree in about 6 weeks. The insect gets its name from its pale, silvery grey wings that resemble the coat of an ermine weasel.

The moths first appeared in this country on homeowners' apple trees in western Washington in 1985. Recently, the moths showed up east of the Cascades in the part of the state that's world famous for its apple orchards.

"We're hoping the wasps will suppress ermine moths on backyard trees and in abandoned orchards in western Washington," says Unruh. "If the wasps flourish, we'll share them with apple growers in eastern Washington."—By **Julie Corliss** and **Marcia Wood**, ARS.

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Spying on Silage Inoculants

Some people put up pickles or sauerkraut in glass jars. Agricultural engineer Richard E. Muck does his preserving in mini-silos—in a laboratory.

These mini-silos are used to check the effectiveness of bacterial inoculants that farmers use to improve silage quality and animal performance.

"In a large farm silo, it's difficult to see what's happening to silage," says Muck, who works for ARS at the U.S. Dairy Forage Research Center in Madison, Wisconsin. But the mini-silos, which are made of clear plastic tubes, provide a quick look at what's going on.

"Although we don't make inoculants, our research can help farmers with day-to-day decisions about using them and what to expect," says Muck.

Most inoculants hasten and improve silage fermentation, but this doesn't necessarily result in the cows eating more dry matter and producing more milk. So farmers need information on the conditions under which the inoculants can be the most cost-effective to their operation, says Muck.

At the U.S. Dairy Forage Research Center, director Larry D. Satter fed test groups of cows alfalfa silage treated with bacterial inoculants, evaluated their performances, and compared results to data from cows fed untreated silage.

"For cows to eat more or to produce more milk, the inoculant has to boost the lactic acid bacteria on the crop at the time of ensiling by 10 times," says Satter.

In studies where the amount of lactic acid bacteria was increased this much or more by the inoculant, he found a 2.5 percent increase in milk production. This represents a return of $2.50 for every dollar invested in the inoculant, says Satter.

If the inoculants are used indiscriminately, the average increase in milk production is only 1.2 percent, meaning a return of about $1.20 for every dollar invested.


BRUCE FRITZ

To evaluate experimental silage inoculants, agricultural engineer Richard Muck examines a mini-silo. (K-4207-1)

To get a higher rate of return on inoculant use, farmers need a way to predict natural populations of lactic acid bacteria on a crop.

Factors influencing the natural lactic acid bacteria on a crop are wilting time, temperature, and moisture content of the alfalfa at ensiling.

After 5 years of survey work and testing in Wisconsin, Muck has produced mathematical equations and graphs that farmers can use in predicting natural populations of lactic acid bacteria. This information was distributed earlier this year to Wisconsin dairy farmers.

Muck has also experimented with a bacterial strain originally isolated by scientists in Great Britain. Although not yet commercially available, *Streptococcus bovis* is a natural bacterium found in a cow's rumen. "It looks promising as a supplement to bacteria used in commercial inoculants because it increases acidity of fermenting silage up to 50 percent faster than commercial inoculants now in use.

"We know the inoculants help animal performance, but we're still studying the specific ways they increase milk yield or feed intake. Getting the pH to drop more quickly helps preserve the protein in the crop, and that means a more nutritious meal for cows," says Muck.

He is further checking the effectiveness of the equations in other parts of the country. Wisconsin, California, New York, Pennsylvania, and Minnesota are the leading dairy states.—By **Linda Cooke,** ARS.

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More For Less

A New Way To Grow Tomatoes

A new way of growing tomatoes bears good news for both growers and the environment.

"Plant mulches are the key to our success," says Aref A. Abdul-Baki, a plant physiologist with USDA's Agricultural Research Service. "We used hairy vetch instead of the traditional black polyethylene mulch in two separate tomato plantings this year. We got some amazing results."

Hairy vetch mulching increased yield by about 138 percent and reduced insect infestation to the point where it was hardly a problem, Abdul-Baki says. An added bonus: No tillage and less fertilizer, herbicides, and pesticides.

Unlike plastic, plant mulches add organic matter to the soil and increase its water-holding capacity. Also, vetch is a legume that adds nitrogen, thereby reducing the amount of fertilizer needed.

He says that growers typically use black plastic mulch to improve yield and to promote early crop maturity. However, polyethylene material doesn't degrade, so it must be removed and disposed of each season—an expensive, labor-intensive practice and one more problem for landfills.

Tomato plants growing in vetch plots were greener and bigger than plants in plots where plastic, paper, or no mulches were used.

Yields from plants grown under the vetch mulch averaged more than 45 tons per acre, trailed by 35 tons for plastic mulch and 34 tons for paper. Control plots with no mulch at all averaged 19 tons per acre.

Last fall in experimental tomato field plots at the ARS Vegetable Laboratory in Beltsville, Maryland, Abdul-Baki and colleague John Teasdale planted hairy vetch, a fairly common legume used as ground cover, on prepared beds. They mowed the vetch to about an inch high in the spring, then immediately planted tomatoes in the plots without turning up the soil or disturbing it at all.

"Immediately after planting, it was hard to distinguish the green tomato plants from the cuttings of freshly mown vetch," says Abdul-Baki. But within a few days the cuttings dried, forming a heavy, brown matted covering.

"This matted residue suppressed early-season weeds, eliminating the need for preplant herbicides," adds Teasdale, a plant physiologist in the ARS Weed Science Laboratory at Beltsville. A chemical was used only for those weeds that emerged later in the season.

Weeds were stifled by other mulches, but paper mulch didn't allow much water to pass through to aid the plants. However, unlike plastic, it prevents heat buildup under the mulch.

SCOTT BAUER

Plant physiologist Aref Abdul-Baki evaluates vetch mulch thickness and effectiveness in reducing soil temperature and water loss. (K-4175-13)

As for insects, Abdul-Baki says, "A surprise was the absence of Colorado potato beetles." This reduced the amount of pesticides needed. The Colorado potato beetle is a major problem for tomatoes during the first month after field planting.

Infestation by the beetle was severe in adjacent plots where plastic and paper mulches were used.

Abdul-Baki plans to pull up the test tomato plants, roots and all, at the end of the growing season, and remove them from the field for mulching and recycling. The beds will not be disturbed.

He will reseed with hairy vetch in the fall, mow in the spring, and transplant tomatoes without tillage.

Once the technique is refined, Abdul-Baki thinks it might work for other vegetable crops.—By **Doris Stanley,** ARS.

Aref A. Abdul-Baki is at the USDA-ARS Vegetable Laboratory. Phone (301) 344-1729. John Teasdale is at the USDA-ARS Weed Science Laboratory. Phone (301) 344-3504. Both labs are at the Beltsville Agricultural Research Center, 10300 Baltimore Ave., Beltsville, MD 20705-2350. ◆

SCOTT BAUER

Healthier, more vigorous, more productive tomato plants result from a mowed-vetch system (above). Plants below were conventionally grown. (K-4230-9)

SCOTT BAUER

(K-4230-10)

ROB FLYNN

Computers Guard the Granary

A new computer program under development will estimate the amount of energy and chemicals needed to control stored grain pests, says James E. Throne of USDA's Agricultural Research Service.

"What we're trying to do is improve the cost-effectiveness of stored grain pest control and reduce the amount of pesticides used in stored grains," says Throne, a research entomologist with ARS' Ecology and Biological Control Research Unit in Savannah, Georgia. "This program predicts the best storage conditions for keeping the population of insects below the level requiring treatment."

Throne and fellow entomologists Richard T. Arbogast and L. Daniel Cline have studied the living, breeding and eating habits of the five major enemies of stored grain for the past 3 years. Once all of the information is collected and added, the program will use mathematical calculations to determine under what conditions insects are likely to infest grain.

Targeted insects include the maize weevil, rusty grain beetle, flat grain beetle, Indianmeal moth, and red flour beetle. Insects are studied at the egg, larval, pupal, and adult stages.

"We still need a couple more years of data before we can come up with a program that can be useful in predicting insect activity," Throne says. "If we can predict insect growth, we can lower the amount of pesticide needed to control these pests."

The program could be used by industry, grain elevator operators, and in the future by farmers to properly administer controls that deter insect growth.

Moisture and temperature are two primary conditions that spur insect growth. Throne, Arbogast, and Cline are monitoring insect activity of these major pests under various moisture levels and temperatures.

Currently, one way to control temperature is by refrigerating grain bins. The warmer the temperature, the more grain a pest will eat.

"But refrigeration is too expensive," Throne says. "Ultimately, prices for products would increase."

In Savannah, for example, it would cost about 0.9 cents per bushel each month to maintain grain at 60°F, the temperature required to protect against insect infestation.

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Red flour beetle

So the scientists have monitored the rate of insect development and the number of eggs laid by insects at temperatures ranging from 50°F to 95°F in 5° increments. This is the primary range for insect activity. Improper temperature in grain can also lead to mold growth.

Keeping a storage bin properly ventilated certainly helps maintain quality during cooler parts of the year, but ultimately grain stored for long periods of time must be fumigated to keep pests from getting in.

Even in warm areas, such as the South, ventilation can be used to keep the storage environment unsuitable for insect growth from harvest until summer. However, during the summer, fumigation will be needed at some point.

If the moisture level inside a grain bin is generally below 11 percent, insect activity should decrease, Throne says. That's because the grain becomes too dry for insects to eat or lay eggs.

As the moisture content increases above 11 percent, it becomes better suited for insect growth. And at 14 percent or higher it's ideal for both insect and mold growth.

Insect damage can decrease the nutritional value of stored grain, lower grain weight (which reduces the price to the farmer), and leave unwanted residues. Infestation can also hurt exports by lowering grains' dollar value and perception of its quality.

The program could provide information about proper storage conditions to those who store grain and help them decide whether fumigants will be needed to control pests. It can also predict when, and in what numbers, biological controls should be used, if the Environmental Protection Agency approves their application to stored grain.

The model also suggests the potential effects of global warming on insect growth and control in grain bins. It simulates pesticide degradation, pest population growth, and what effects a change of 3°F to 8°F may have on insect control.—By **Bruce Kinzel,** ARS.

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Grain storage bins near Savannah, Georgia. (K-4289-1)

Exotic Fruits Promise Taste of the Tropics

Sweet and juicy, the exotic fruit lychee ranks as one of Asia's most enduring taste treats. Farmers in China have cultivated lychee for more than 2,000 years.

Today, lychee and its relatives rambutan and pulasan are among more than a dozen tasty tropical fruits and nuts that are safeguarded at the ARS tropical crops gene bank in Hawaii. It's a home for pineapple, passionfruit, papaya, breadfruit, macadamia nuts, guava, and carambola or starfruit. Plus, there's a handful of other species most Americans have probably never heard of, like atemoya (also called custard apple), pili nuts, peach palm, and acerola cherry.

Tucked in the Panaewa rainforest about 8 miles outside the town of Hilo, the collection is a living array of seeds, cuttings, plantlets, trees, and vines of wild, rare, and commercially grown tropical plants.

Curator Francis T.P. Zee works closely with entrepreneurial growers in the Hawaiian Islands. These growers are intent on making it as easy to buy a fresh lychee or rambutan in mainland supermarkets as it now is to pick out a fresh pineapple or bunch of bananas.

To make that dream come true, growers need lychee and rambutan trees that will thrive in Hawaii. That's why some of the farmers have made plant-collecting expeditions to southeast Asia and elsewhere—just as Zee has done. They scout village fruit stalls, comb orchards of friendly local farmers, and check row upon row of fruitbearing trees in research groves, looking for promising lychees and other fruits that might appeal to American consumers.

The globe-trotting growers typically share their botanical finds with Zee and exchange tips on nurturing the rare crops.

JACK DYKINGA

Curator Francis Zee inspects papaya trees. (K-3504-7)

They want first to fulfill the demand for luscious tropical fruits to market to the state's 1 million residents. But the farmers have also targeted the tourist industry: Even though Hawaii hosts about 1 million travelers every year, few tropical fruits end up on menus visitors are likely to see.

"Most tourists to Hawaii will probably eat some pineapple and perhaps some papaya," says Candace Strong of Kahili and Kilohana Farms on the island of Kauai. "But the majority will likely go home without ever tasting a lychee, rambutan, or other exotic fruit."

"The fruits grown here are typically very high quality," notes Eric Weinert, president of Hawaii Tropical Fruit Growers, a trade association. "We have a lot of agricultural land here, and we have the potential to make these fruits commonplace at supermarkets in Hawaii and on the mainland."

Lychee has firm, translucent, milky-white flesh that's eaten fresh, canned, preserved, or dried into a chewy, caramel-like snack.

The fruit's skin, usually red, pink, or red with green, is thin, bumpy, and easy to peel. Each walnut-sized lychee contains a seed. In some varieties, seeds are about the size of a marble. Others have flat, shriveled seeds called chicken tongue because that's what they look like.

Lychee is produced in Australia, China, India, Mexico, South Africa, Taiwan, and two American states—Hawaii and Florida. Hawaii's harvest is from numerous backyard trees and some commercial orchards. Florida has from 150 to 200 acres of lychee orchards. Most are young trees, planted within the last 5 years to meet the demand from people who've come to America from southeast Asia. The Florida crop, shipped primarily to East Coast or Midwest markets, is worth almost $2 million a year.

Changes in tropical farming in Hawaii and Florida have nudged more growers into taking a new look

at raising lychee and other exotics. Sugarcane's decline in both states has freed up canefields for other crops. Too, U.S. consumers have shown a new willingness to try exotic fruits and vegetables. And growers elsewhere—most notably in Australia—have tried planting exotics with remarkable success in the last 10 years.

Zee's expedition to Taiwan earlier this year netted 12 new types of lychee. The gift of a Taiwanese experiment station horticulturist, Chung-Ruey Yen, the plants are now growing at the gene bank.

The botanical bounty includes what Zee describes as "the king of lychee varieties. It's very sweet with a small seed," he says. "This is the best lychee variety in China. But we've never been able to produce a good crop from it in Hawaii. The tree grows well but doesn't produce fruit consistently."

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Hold the fruit at the top and bottom, give it a quick twist to remove the skin, and the sweet, crunchy rambutan is ready to eat.

RICHARD NOWITZ

Pineapple growing in Hawaii. (K-4281-1)

Zee's hoping for better luck with the new material. "It may be a clone of lychees originally collected a long time ago on mainland China," he says.

Lychee's relative, the golf-ball-size rambutan, sports long, soft, bizarre-looking spines. Rambutan may be red to yellow, with red, green, or yellow spines. It "looks like a Christmas tree ornament," says grower Candace Strong. "Rambutan is so attractive that when you see one, you just want to grab it and eat it."

Inside, rambutan's flesh is "pearly-white, sweet, crunchy, and juicy," says curator Zee. "You take the skin off by holding the fruit at the top and the bottom and giving it a quick twist."

Susan Hamilton of Hula Brothers farm in Kurtistown, Hawaii, vouches for rambutan's pleasing flavor. "You don't need an acquired taste to enjoy rambutan," she says. "It's not like a durian," a tropical fruit with so strong an odor that some hotels forbid guests from bringing it inside. "Durian," Hamilton says, "is the kind of fruit that you either love or hate."

Native to Malaysia, rambutan can be eaten fresh, canned, stewed, or in jams and jellies. Thailand, one of the world's largest exporters of canned rambutan, sells about $2.5 million worth of the fruit each year, says Zee.

Rambutan specimens that Zee brought back from his plant-collecting foray to Thailand earlier this year include seeds from the fruit of a 50-year-old tree—a variety of rambutan that no one grows anymore, Zee says. So why put them in the gene bank? "Those trees might have a characteristic, like vigor or disease resistance, that we'll need someday," he says.

Zee also took home seeds of another species, a rambutan relative called *Nephelium hyperleucum.* He found it growing just outside a Buddhist wat, or temple. At that wat, and some others scattered throughout Thailand, the grounds are kept as natural as possible. Inadvertently, the sites have become sanctuaries for native plants.

"At one temple, I saw huge trees growing in a courtyard, sheltering monks and pilgrims," Zee says. "I knew then that those trees and others would be safe as long as there are temples.

"This was the first time on the collecting trip that I didn't have a sense of despair about trying to rescue vanishing species of plants."

At roadside stands in Hawaii, rambutan sells for about $6 a pound. The ideal rambutan for that state would bear fruit in the winter, the off-season for Thailand's orchards. A few varieties at the gene bank might fit that niche, he says.

Other promising rambutans include wild trees that produce unusually dark, purplish-red fruit. Zee and colleagues Robert J. Knight and Raymond J. Schnell of the ARS Subtropical Horticultural Research Laboratory in Miami brought back specimens of the uniquely colored rambutans from Borneo last year.

Zee says the fruits are likely to have more acid and less sugar than typical rambutan varieties. That sweet-tart balance gives the wild fruit "a pleasantly acidic flavor, probably closer to that of fruits Westerners are used to eating," he adds. The trait might boost rambutan's appeal if the fresh fruit were introduced to mainland U.S. markets.

Another prize from that expedition was seed from a giant rambutan. It yields jumbo fruit about twice as large as ordinary rambutans.

Right now, neither fresh lychee nor fresh rambutan can be shipped to the mainland from Hawaii. That's because both fruits are host to tropical fruit flies that other states and nations want to keep out.

BARRY FITZGERALD

Lychee, a sweet tropical fruit, is a good source of vitamin C. (K-2296-2)

No Hitchhiking Insects

How can Hawaii's fruits be protected from fruit flies that want a free ride to the mainland?

Dipping lychee in a hot bath, or chilling it, are two promising tactics for destroying any fruit flies that might be hiding inside the fruit, says research entomologist John W. Armstrong. He works at the Tropical Fruit and Vegetable Research Laboratory next door to the gene bank.

A technique to make sure that exported lychee is free of tropical fruit flies might be ready by late next year, Armstrong estimates. Finding a way to zap fruit flies in rambutan, however, will probably take longer. Techniques that have worked well with other crops, says Armstrong, so far haven't succeeded for rambutan.

Meanwhile, mainland produce businesses like Frieda's Finest, the largest broker of specialty produce in the United States, sell lychee but can't keep up with the current demand. Similarly, the company gets requests for fresh rambutan but they can't fill them.

Frieda's buys fresh lychee from both Florida and Mexico, selling as much as 100,000 pounds each year, according to Bess Petlak at the company's Los Angeles, California, headquarters.

Says Petlak, "We get calls all the time for fresh rambutan, but we can't supply it because of the fruit fly problem. When the researchers get the bugs worked out, we're ready to sell it."—By **Marcia Wood,** ARS.

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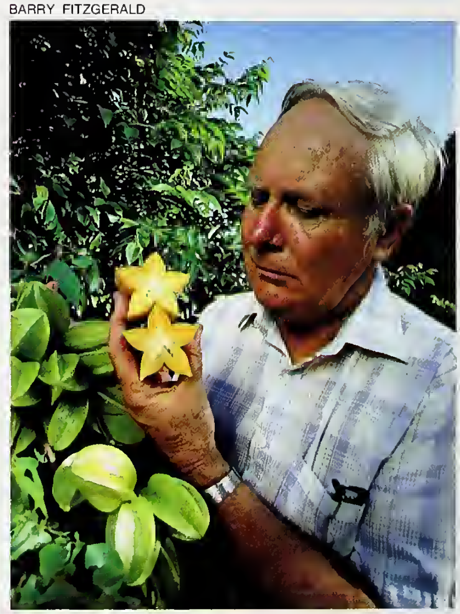
BARRY FITZGERALD



Horticulturist Robert Knight with carambola fruit. Fruit in foreground has been cross-sectioned to show the distinctive star shape. (K-2285-3)

In Antibodies, Bigger Isn't Always Better

Like a stretch limo trying to get into a mini-car parking space, an antibody too large to get where it's needed may handicap dairy cattle in their fight against infection.

ARS scientists studying the migration of white blood cells into the udders of dairy cows showed that IgM, an important antibody circulating in the blood, did not successfully migrate with the white blood cells to the udder when infections or inflammation occurred.

"On the other hand, IgG_2, another antibody, or immunoglobulin, stayed attached to the white blood cell, or neutrophil, and made it through the membranes surrounding the udder in fine style," says Max J. Paape of USDA's Agricultural Research Service.

Furthermore, he says, "we found that during their journey through the membranes, neutrophils developed more antibody binding sites. This may increase their ability to bind specific antibodies and attack bacterial invaders."

Paape, who works at the ARS Milk Secretion and Mastitis Laboratory, Beltsville, Maryland, says ways to increase the binding of immunoglobulins to neutrophils in milk may improve protection against udder infection.

Such infections cost dairy farmers $2 billion annually in medication and lost milk production.

In laboratory tests, University of Maryland graduate students Leanne Berning and Millie Worku, who worked with Paape, used a chamber partitioned by a filter with pores about half the size of the neutrophils.

On one side they placed a suspension of neutrophils that had IgG_2 and IgM immunoglobulins attached to their surfaces. On the other side was a special mixture of fetal calf serum that acted as an attractant to the neutrophils.

After 3 hours the neutrophils that migrated through the membrane were examined in a special cell sorter. The neutrophils lost most of the IgM, but the IgG_2 immunoglobulin numbers were about the same. Further, new binding sites for IgM and IgG_2 appeared on the cell surface.

SCOTT BAUER

Research assistant Millie Worku operates a flow cytometer, a laboratory instrument that reveals how immunoglobulins bind to neutrophils. (K-4241-1)

"To see if the results could be repeated in dairy cows, we placed an irritant in their udders to simulate an infection. Neutrophils tested at the site of the bogus infection had also lost their IgM immunoglobulin and had increased numbers of binding sites," says Paape.

Paape speculates that, "because the IgM is so much larger than the other molecules, it is rubbed off in the rather small pores of the membranes as the neutrophils squeeze through."

Antibodies circulate in the blood and are formed when the body's immune system recognizes a "stranger." They are instrumental to the destruction of invading bacteria.

Paape says that "antibodies ride piggy back on neutrophils. They act like antennae to locate the offending bacteria, which the neutrophils then stick to. Ultimately, the neutrophil ingests the bacteria through a process called phagocytosis."—By **Vince Mazzola,** ARS.

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Skipping Preplant Irrigation Saves Water, Cash

Sometimes saving a resource such as underground water pays off—immediately and in cash.

A 4-year study has shown that sorghum farmers in the Texas High Plains can save about $4 an acre in fuel cost by not turning on their irrigation water before planting.

These farmers tend to heavily water furrow-irrigated fields before seeding. This assures them enough moisture for timely planting and germination. This one preplant irrigation requires as much as a third of the water that will be used for the entire season, says Ron Allen, an Agricultural Research Service engineer at Bushland, Texas.

Allen found an average 10 percent yield gain with this practice, worth $21.85 an acre.

But farmers have to use $26 worth of natural gas to pump water for the preplant irrigation, Allen says. This results in a net loss of $4.15 an acre at today's prices.

Allen factored in all the minuses and pluses in his financial figures.

One of the minuses of skipping the preplant irrigation is that farmers may have to wait for rain before planting. In 2 out of 4 years, the rain came almost a month late.

"You're playing with probabilities," he says.

But a plus is that the irrigation furrows don't have to be built before planting. Moistening the seed zone of a flat surface should require less rain than for raised beds formed with dry surface soil, he says. Also, rain from an intense thunderstorm tends to run off beds into furrows.

There was even some yield loss with the preplant irrigation one year. This was caused by a nitrogen deficiency from fertilizer washed out of reach of crop roots by the initial irrigation.

The study also revealed that more than half of the preplant irrigation water is lost to seepage and evaporation.—By **Don Comis**, ARS.

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Insecticide Adherence Triples With Soybean Oil

Oil and water don't mix. And that's helpful when applying the insecticide chlorpyrifos to corn to control corn earworms.

Mixing the insecticide with a soybean oil solution and then injecting the mixture into irrigation water makes it more effective for controlling insects, says ARS chemist Don Wauchope.

When applied this way through center-pivot irrigation systems, the insecticide-oil mixture forms droplets in the spray water that stick to the corn leaves better.

Wauchope, who is with ARS' Nematodes, Weeds, and Crops Research Laboratory in Tifton, Georgia, conducted field tests on sweet corn in cooperation with ARS scientists John Young, Luz Marti, and Harold Sumner and University of Georgia scientist Richard Chalfant. The 1990 tests showed that three times more chlorpyrifos stayed on the corn leaves than when the standard water-soluble formula of the insecticide was injected.

And the chlorpyrifos broke down just as quickly after spraying—lasting only 4 days on foliage and 2 weeks on the soil surface.

This method of applying insecticides is adaptable to many other insecticides and crops, says Wauchope.—By **Dvora Aksler Konstant,** formerly ARS.

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Sorghum

Sorghum Cleanses Nitrogen Laden Soil

Crops that clean up nitrogen and other groundwater pollutants may help solve waste disposal problems in cities and livestock feedlots.

ARS researchers in Lincoln, Nebraska, report that sorghum has an exceptional ability to absorb nitrogen from the soil, thanks to its extensive, fibrous root system.

"We've been able to capitalize on sorghum's natural ability to act as a scavenger of nitrogen," says agronomist Kenneth J. Moore.

He and ARS plant geneticist Jeffrey F. Pedersen are developing a system in which nitrogen can be recycled safely and economically. They propose planting sorghum in highly contaminated nitrogen soils, cutting it several times through the growing season, and feeding the sorghum as silage to livestock.

In the Midwest, municipal and livestock wastes are commonly disposed of by applying them to fallow cropland. "By planting forage sorghum in a well-managed cropping system, producers can safely recycle nitrogen from organic wastes," says Moore.

AGNOTES

Two years ago, Moore and Pedersen began their 5-year project by planting several types of sorghums at the Northeast Lincoln Wastewater Disposal site: grain, forage, sorghum-sudangrass hybrids, tropical, and sweet sorghums.

The sorghum-sudangrass crosses and the tropical sorghums absorbed the most nitrogen from the soil. At the test site, which had 360 pounds of nitrogen applied in the form of sewage sludge, these two hybrids removed an average of 200 pounds of nitrogen and yielded more than 8 tons of dry matter per acre.

"We hoped for more, but the first year proved to be a short, cool growing season. Under normal growing conditions, some tropical sorghums use as much as 300 pounds of nitrogen and yield 20 tons of dry matter per acre," says Moore.

"Since sorghum-sudangrass hybrids are very popular now in Nebraska and other Central Plains and Midwest states, they could be put immediately to work consuming organic wastes," says Pedersen.

Livestock producers have one major concern about forage produced on high nitrate soils—the possibility of nitrate toxicity. To address this, the researchers rated their sorghums for nitrate content. Most were at or near toxic levels, but could be ensiled to reduce the threat of nitrate toxicity.

"We select hybrids for maximum nitrogen uptake, then we look for fast regrowth potential under an intensive cutting schedule with multiple injections of organic waste. We're looking for hybrids with these factors and high-quality forage that doesn't produce toxicity in livestock," says Pedersen.—By **Linda Cooke,** ARS.

Kenneth J. Moore and Jeffrey F. Pedersen are in the USDA-ARS Wheat, Sorghum, and Forage Research Unit at the University of Nebraska (East Campus), 344 Keim Hall, Lincoln, NE 68583. Phone (402) 472-1561. ◆

Please Release Me—But Slowly

There's a family of compounds called cyclodextrins that are adept at letting go.

The three compounds, differing in molecular ring size and made from cornstarch, serve as "hosts" or traps for other substances, which they slowly release.

The substances that have been encapsulated in this way include pharmaceuticals, pesticides, perfumes, cosmetics, and foods. Their gradual release can be triggered in several ways, including exposure to moisture.

Cyclodextrins are ideal for shielding drugs or nutrients from premature deterioration caused by oxygen and for masking undesirable flavors.

Until now, however, it hasn't been practical to encapsulate certain products. Although cornstarch is inexpensive, cyclodextrins have been costly to make and purify, says ARS chemist Jacob A. Rendleman, Jr., of the National Center for Agricultural Utilization Research, Peoria, Illinois.

Especially costly is gamma-cyclodextrin with a "donut hole" larger than those of alpha- and beta-cyclodextrins. Its cavity is easily capable of binding cyclic molecules that have 12 or more atoms in their rings.

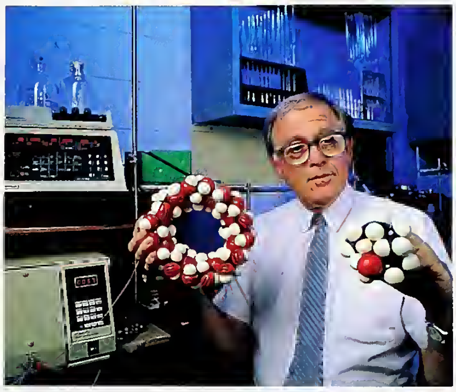
Prices for gamma-cyclodextrin have been about 100-fold greater than those of beta-cyclodextrin over the past 10 years, but they are drifting downward with prospects of market competition, according to an industry spokesperson.

Rendleman's studies may lead to cheaper production and increased use of gamma-cyclodextrin. Until he recently found a way to convert up to 50 percent of starch into gamma-cyclodextrin, a typical yield was 5 percent unless processes were involved that require toxic or more expensive materials.

Currently, worldwide sales of beta-cyclodextrin are estimated at 2 million pounds, mostly for encapsulating food additives in Japan. But the fastest market growth—estimated at 20 to 30 percent annually—is in pharmaceuticals, where 3 to 5 percent of the specialty product is used.

Cyclodextrins are formed when an enzyme from the bacterium *Bacillus macerans* breaks up starch and reassembles it into the donut-shaped molecules. Biosynthesis begins to shut down with increasing concentration of product in the reaction medium.

BRUCE FRITZ



Chemist Jacob Rendleman uses molecular models to determine the best shape and size for a molecule to bind snugly within the cavity of the donut-shaped gamma-cyclodextrins. (K-4208-1)

Rendleman enhanced the yield of the gamma form by adding a nontoxic 12-carbon-ring compound called cyclododecanone to the reaction medium where it captured and insolubilized the cyclodextrin as it was formed.

Then, in a process called azeotropic distillation, he separated cyclodextrin from the cyclododecanone—which could then be reused.—By **Ben Hardin,** ARS.

Jacob A. Rendleman, Jr., is at the USDA-ARS National Center for Agricultural Utilization Research, 1815 N. University St., Peoria, IL 61604. Phone (309) 685-4011. ◆

Correction

"Blocking Insect Immune Response," in *Agricultural Research,* August 1991, page 25, inadvertently omitted the affiliation of the researcher who led the study. He is David W. Stanley-Samuelson at the University of Nebraska, Lincoln.

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